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Feature

Inquiry and Developing Explanations from Evidence

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As a new student teacher entering a classroom of ninth- and tenth-grade general biology students, I hoped my teaching would include inquiry-based assignments in which students created knowledge as they worked to identify and answer their own questions. I soon discovered the difficulty of accurately assessing student understanding on such projects. The following analysis of one inquiry-based assignment examines students' efforts to build interpretations from evidence.

At the beginning of the school year, my mentor teacher had presented students with a variety of biology themes. The students voted to study biology through the context of drugs. I joined the action as students began the process of brainstorming and selecting a drug to research. We addressed the *National Science Education Standards* as students learned about cells, organelles, the nervous system, and neuronal impulses (Standard C) in preparation for a presentation on how their drug functioned (Standard F). This project fits within the Standards definition of scientific inquiry in several ways (NRC 1996, p. 176). First, students used previously learned biological concepts and principles to guide their inquiries. Second, students relied on technology (e.g., iBooks, the Internet, PowerPoint) to gather, organize, and present their findings. Third, students constructed scientific explanations for natural phenomena that were scientifically consistent with previous knowledge and new evidence. Finally, students demonstrated their findings by communicating and defending the explanations resulting from their inquiries.

The inquiry project was composed of two parts—an annotated bibliography and a final PowerPoint presentation. My goal was to introduce students to the process of discovering information, understanding their findings, and arranging that information for presentation (Standards A and E). Because students

were working either individually or in pairs with each group investigating a different drug, the presentation guidelines (Figure 1) focused on the audience gaining basic information about the drug and elements of the cellular mechanism by which the drug functioned.

Independent project: Drugs

This project will provide you with the opportunity to research a drug—licit or illicit—and present your findings to your classmates. You should research and prepare to present the following information:

- General information about the drug, such as the drug's name, the class of drugs it belongs to, its chemical formula, and its source.
- When, where, and how the drug is used, including its dosage and its desired effect on the body.
- How the drug works at a cellular level.
- Side effects of the drug and medical treatments for the side effects, including an overdose.
- Potential for and cause of addiction to the drug (note: licit drugs can also cause addiction).

This semester we have covered cells in detail. Thus, the cellular interactions of a drug should be your focus during research and presentation. If the drug interferes with the functions of neurons and synapses, how does it do so?
When conducting Internet research, always consider the source. Use information from credible sources only (e.g., organizations, scientific publications). If you cannot find the author(s) of a website, do not consider its information to be factual.

Project presentations
All group members must participate in oral presentations. Your project will be graded on the following criteria:

Content: Does your project convey sound, biology-based information?

Effective communication: Does your project hold the attention of the audience? Is the information presented in a clear and understandable fashion (whether verbal or written)? Are the visual aids attractive and easy to interpret? For oral presentations, is the delivery effective (including use of visual aids, appropriate speaking pace, and poise)?

Quality and suitability of references: Is there a sufficient number of sources to support the information in your project? (Your group should have a minimum of three, but more will usually be necessary to obtain all the information required to cover the topic.) Are the chosen sources appropriate?

Knowledge and ability to answer questions: No one will be able to answer every question about the topic, but how comfortable are you with the information? Are you able to talk about your topic rather than

just reading your notes?

Creativity: Creative touches greatly enhance the quality of a project. However, make sure that the creative aspect does not distract from the content and communication.

Overall quality: Is your project neat? Is there evidence of effort?

The annotated bibliography assignment was meant to create a supporting framework for student success on the final presentation. After introducing students to the purpose of an annotated bibliography, I gave them their goal: To compile an annotated bibliography of six different websites pertinent to their inquiry. Students created their bibliographies as they conducted Internet research.

When assessing the products of the annotated bibliography, I was pleased with student progress. Almost all students had completed substantial research and had progressed nicely toward obtaining all the information necessary to present. However, the presentations did not mirror the consistently high level of success on the bibliographies. While almost all presentations included basic information about the drug (e.g., chemical formula, how it is produced), some lacked crucial process-based information, such as how the drug functioned at a cellular level and neuronal explanations for behavioral responses. I was frustrated by this disparity in success. Why had some students who had done very well on the annotated bibliography performed poorly on the presentation while other students had achieved highly on both?

Designing assessments

When I designed the inquiry, I assumed both the bibliography and presentation would require similar intellectual demands. In an effort to understand the dichotomy of success on the two assignments, I considered how the assignments fit more specifically within accepted constructs of scientific inquiry. Initially, I identified both assignments as guided inquiry because of the origins of the investigative questions. I gave students general questions to investigate, such as, "How does the drug work at a cellular level?" and, "Are addictive properties associated with this drug?" I expected students to branch out from my questions in their research, creating new questions, such as, "If there are addictive qualities associated with the drug, what are they?" and, "How do those qualities come about?" To me, the presentation was a natural progression from the bibliography. However, as I continued to examine the complexities of classroom inquiry, I began to recognize how the assignments were not as complementary as I envisioned.

Lisa Martin-Hansen identifies four forms of scientific inquiry that range from student-centered to teacher-centered. These four forms of scientific inquiry are open/full inquiry, guided inquiry, coupled inquiry, and structured inquiry (2002). Martin-Hansen provides five "essential features of classroom inquiry and their variations": questioning, using evidence to answer questions, formulating explanations, connecting to scientific knowledge, and communication (2002, p. 36). Each of these features has variations ranging from minimally student-centered to minimally teacher-centered (Figure 2. This figure

can be accessed by clicking here. The figure will open in a new window.). By using Martin-Hansen's framework to analyze the two assignments, I found that the bibliography was not as preparatory as I had initially envisioned. While both assignments emphasized the first two essential features of inquiry (the source of the investigative question and the determination of valid data), the similarity ends there.

This framework has helped me realize that I had established no expectations for my students to formulate explanations from evidence (Essential Feature 3) or make connections to scientific knowledge (Essential Feature 4) in the annotated bibliography assignment. This contrasts with the expectations of the presentation, where students were expected to independently construct a scientific explanation for the cellular function of a drug and connect their new knowledge to previous class topics. I now recognize the annotated bibliography assignment supported learning and success on the presentation to a certain extent, but it left some students without enough support in areas emphasized in the presentation.

Reexamining student work

On the annotated bibliography handout, I gave students specific criteria for the presentation of findings. With these supports, students were explicitly told the expectations and exactly how to be successful. When assessing the assignment, I awarded points for achieving specific criteria. I discriminated minimally in regard to content. A sentence with significant evidence of interpretation was awarded the same points as one that only scratched the surface of in-depth interpretation. In contrast, when introducing the presentation portion of the inquiry, students were given suggestions for developing their projects but were not given strict guidelines. When assessing, I evaluated based on the level of scientific detail shown and the ability to respond to questions.

One purpose of the annotated bibliography was to have students recognize high quality and substandard sources. I intended for students to identify a quality source, interpret their findings, and develop a few sentences about the website. Wiggins and McTighe advocate that teachers should actively seek "salient and revealing criteria for identifying and differentiating levels or degrees of understanding—using criteria and rubrics to sort work by quality on a continuum" (1998, p. 67). This suggestion is very different from the straightforward criteria I had used to assess the assignment.

With this new perspective, I revisited the bibliographies. Two examples of student work provide insight into my findings (Figure 3). Both entries met the minimum requirements (a complete Web address and three sentences about the website), and both earned full points. However, Entry A provides evidence of understanding that is not present in Entry B. Entry A demonstrates understanding by using biologically technical language and identifying and explaining process-based information. I have a sense this student critically examined the website, evaluated its information for quality, and worked to accurately interpret the findings. Entry B, in contrast, provides little scientific information, makes no use of technical language, and does not provide any evidence of understanding how the drug functions. This student probably did not perform more than a cursory examination of the site's content, had no regard for the quality of the

information, and did not work to interpret the information.

Figure 3. Sample annotated bibliography entries from two students in the same class.	
Entry A: Prozac	faculty.washington.edu/chudler/chnt1.html A website that gives good information on serotonin, a type of neurotransmitter that Prozac affects. It gives other human behaviors that involve serotonin, not only a person's mood or with obsessive compulsive disorders but also with hunger, aggressive behaviors, the onset of sleep, and perceptions. It also explains and goes through the processes of sending an action potential and where serotonin fits in with the whole process.
Entry B: Ecstasy	faculty.washington.edu/chudler/mdma.html This site features some facts and an article: What is mdma, behavior effects, and brain damage. It also shows a graph about how many hospital visits have been made off of this drug-related problem.

After examining multiple annotated bibliographies and placing them on a continuum of quality as Wiggins and McTighe suggest, I found that the level of understanding evidenced in the presentations was represented in achievements on the initial assignment. Even though my initial grading showed widespread student success, placing student work on a continuum allowed me to recognize how closely their work at this intermediate step revealed their understanding. When I assessed student work looking only for quantitative characteristics of learning, as I did when I initially examined the bibliographies, I missed the crux of student understanding. The point-driven subjective criteria I had developed for grading the annotated bibliographies were not consistently reflective of my students' understanding. As a result, I did not recognize the signals my students were sending me about their level of understanding, and did not provide additional guidance to those that needed it.

Supporting and assessing student inquiry

I now understand the importance of building interpretations from evidence as a part of scientific inquiry. While this project was successful in that students actively engaged in learning and gained both process and content knowledge, I need to make some changes before incorporating it into a course again.

The changes I will make are more reflective of adjustments to all inquiry projects rather than specific changes to this project. When I design future inquiry projects I will ask, "What would I consider evidence of understanding on this task?" and "Have I asked students to present me with this evidence?" As I develop a rubric or criteria for assessment, I should be asking myself questions such as, "What does this tell me about my students' level of understanding?" and "What evidence do I have to support this claim?" These kinds of questions will help ensure that I am supporting learning and being clear about my expectations and the evidence I consider appropriate for meeting those expectations.

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References

Martin-Hansen, L. 2002. Defining inquiry: Exploring the many types of inquiry in the science classroom. *The Science Teacher* 69(2): 34–37.

National Research Council (NRC). 1996. *National Science Education Standards*. Washington, D.C.: National Academy Press.

Wiggins, G., and J. McTighe. 1998. Thinking like an assessor. In *Understanding by Design*, 63–84. Alexandria, Va.: Association for Supervision and Curriculum Development.